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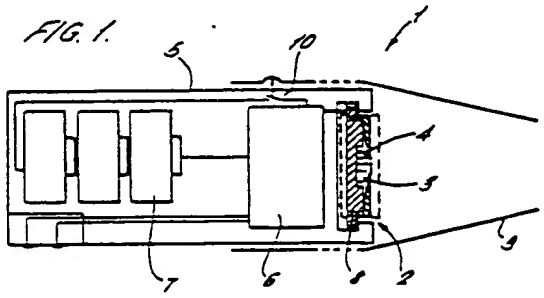
(54) Dispensing apparatus.

(57) A liquid atomising dispenser has a perforate membrane (13) vibrated by a piezoelectric transducer (8) such that atomised droplets are dispensed through holes in the membrane. The holes are flared so as to increase in cross-section in a direction from a rear surface contacted by liquid towards a front surface. The dispenser is suitable for dispensing pharmaceutical products including particulate substances in suspension.

FIG. 1.



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Conveniently the vibrating means comprises a transducer removably connected to the housing whereby in use a housing from which liquid has been dispensed can be replaced by a further housing charged with liquid.

Preferred embodiments of the present invention will now be described by way of example only and with reference to the accompanying drawings of which: -

Figure 1 is a schematic section of a hand held dispensing apparatus;

Figure 2 is a schematic section of the apparatus of Figure 1 connected to an electronic control unit;

Figure 3 is a sectional elevation of the spray head of the apparatus of Figures 1 and 2;

Figures 4, 5, 6 and 7 are sectional elevations of further alternative spray heads;

Figure 8 is a view of the rear face of a perforate membrane for use in a spray head of any of the preceding figures;

Figure 9 is a sectioned elevation of a perforate sheet portion of the perforate membrane of Figure 8; and

Figure 10 is a plan view of a perforate sheet portion of the perforate membrane of Figure 8.

Figure 1 shows dispensing apparatus 1 which is a hand held inhaler for medical use. Apparatus 1 comprises a housing 2 defining a chamber 3 containing liquid 4 to be dispensed.

The housing 2 is mounted on a hand held casing 5 within which is located an electronic control circuit 6 and batteries 7. An electro acoustic transducer 8 of the piezoelectric type is mounted on the housing 2 and is powered and controlled by the control circuit 6. A mouthpiece 9 fits slidably on the casing 5 and movement of the mouthpiece 9 relative to the casing actuates an on-off switch 10.

The detailed construction of the housing 2 and transducer 8 can be seen from Figure 3. The housing comprises a disc 11 having a central aperture 12 with a thin perforate membrane 13 bonded to the disc so as to overlay the aperture. The construction of a suitable membrane 13 is described below with reference to Figures 8 and 9. The membrane 13 is perforated by a large number of holes 25 of which only a few are included in Figure 3 by way of schematic representation. The disc 11 has a flat front face 14 and a frusto-conical rear face 15 so that the disc tapers linearly in thickness in the radially inward direction towards the perforate membrane 13.

The disc 11 has a periphery 16 from which projects rearwardly a tubular portion 17.

The housing 2 also includes a circular base 18 which fits within the tubular portion 17 so that a chamber 3 is defined between the base and the disc 11. The base 18 has a front face 19 having a central recess 20 such that the chamber 3 is deepest in the region adjacent to the membrane 13.

An annular rib 21 is formed on the base 18 peripherally of the front face 19 and locates in an annular groove 22 formed in the disc 11 thereby sealing the chamber 3. An annular space 29 is formed between the tubular portion 17 and the base 18.

The transducer 8 is a circular ring piezoelectric element and is bonded to a rearward end 23 of the tubular portion 17.

The transducer 8 is arranged such that when energised with an alternating voltage the transducer expands and contracts radially to impart an ultrasonic vibration to the tubular portion 17. The thickness of the rearward end 23 (measured in the direction in which it is vibrated by the transducer) is considerably thicker than the thickness of the disc 11 at the point of contact with the membrane 13. The disc 11 flexes in response to radially outward movement of the transducer by pivotal action about the annular rib 21 so as to move the membrane 13 axially towards the base 18. On radial contraction of the transducer 8 pivotal action about the rib 21 causes flexure of the disc so as to move the membrane 13 away from the base 18. At ultrasonic frequencies however the movement of the disc 11 can be characterised more in terms of transmission of transverse acoustic wave motion in a direction radially inward through the disc 11. The effect of the taper present in the shape of the disc 11 results in the amplitude of such transverse vibrations increasing progressively in the radially inward direction to thereby maximise the axial displacement of the membrane 13. The increase in amplitude is associated with the decreasing impedance of the disc 11 in the radially inward direction.

In use to dispense liquid, the apparatus 1 is held in an orientation in which liquid 4 is in contact with the rear surface 24 of the perforate membrane 13. Prior to actuation of the transducer 8 there will generally be no loss of liquid through the holes 25 in the membrane 13 since a liquid surface formed in the holes will generally have sufficient surface tension to resist the outflow of liquid. Dispensing operation is commenced by the user actuating the switch 10 so that the transducer 8 is energised to vibrate at ultrasonic frequency. This vibration is conducted by the disc 11 to the perforate membrane 13. During rearward motion of the vibrating membrane 13 an instantaneous pressure rise in the liquid adjacent to the membrane will result in the surface tension being overcome and droplets of liquid being ejected through the holes 25.

A fine mist of atomised liquid is dispensed through the membrane 13 into the mouthpiece 9

droplets are required such that the thickness of the membrane 13 and the size of the holes 25 are less than 20 microns. The membrane 13 may be provided with holes 25 of uniform or non-uniform hole size depending on the required distribution of droplet size.

A further alternative spray head 60 is shown in Figure 7 where corresponding reference numerals to those of previous figures are used where appropriate for corresponding elements.

The spray head 60 has a disc 11 formed of aluminium alloy and having a circular planar front face 14 of 22mm diameter. An annular piezoelectric transducer 8 having an internal radius of 10mm is bonded to a peripheral portion 61 of the front face 14 so as to be radially spaced from a circular central aperture 12 of the disc 11 having a diameter of 4mm.

The disc 11 tapers in thickness in the radially inward direction such that a rear face 15 of the disc 11 has an outer annular portion 62 which tapers at an angle of 20° relative to the front face 14 when viewed in radial section and an inner annular portion 63 which tapers at an angle of 10° relative to the planar front face 14. The inner annular portion 63 joins the outer annular portion 62 at a circular interface 64 which is adjacent the radially inner edge 65 of the transducer 8. The transducer 8 thereby is bonded to a relatively thick outer portion 66. A relatively slender inner portion 67 of the disc 11 defines the aperture 12.

A perforate membrane 13 overlays the aperture 12 and is bonded to an edge portion 68 of the inner portion 67. The perforate membrane 13 as shown in Figures 8 and 9 comprises a nickel sheet 69 having an integrally formed support 70 in the shape of a grid having circular symmetry as shown in Figure 8.

The support 70 comprises thickened elements 72, 73 and 74 of the membrane 13 defining a series of apertures 71 which expose corresponding portions of the sheet 69. The support 70 has an outer annular element 72 which is connected to an inner annular element 73 by radial elements 74 defining the apertures 71 therebetween. A central aperture 75 is defined within the inner annular element 73 thereby exposing a central portion 76 of the sheet 69. The membrane 13 is formed in an electroforming process in which nickel is electrodeposited on selected areas of a substrate masked using a photographic process and the resulting sheet 69 is then detached from the substrate. The outer annular element 72 of the support 70 is bonded to the edge portion 68 so that vibration of the disc is conducted through the support to the sheet 69.

The membrane 13 is coated in a liquid repellant coating 80 using a commercially available surface treatment process in which sub-micron particles of polytetrafluroethylene are incorporated in a nickel phosphorous matrix which is auto-catalytically applied to the nickel material of the sheet 69 and support 70. A small proportion of phosphorous co-deposited with the nickel enhances the corrosion resistance of the resulting finish.

As shown in Figures 9 and 10 the sheet 69 includes a regular array of circular holes 77 and has a front face 78 to which the support 70 is bonded. The sheet 69 has a rear face 79 which is normally contacted by liquid 4 and the holes 77 are flared such that the cross-section of each hole narrows in a direction from the rear face 79 towards the front face 78.

The resulting holes 77 in the sheet 69 are of 3 microns diameter and 25 microns spacing. The resulting droplets are formed in the range 5 to 7 microns when dispensing a pharmaceutical product in aqueous solution, this droplet size being suitable for delivery of atomised products to the lungs of a patient. A typical flow rate in the range 10 to 20 cubic millimetres per second is achieved, the flow rate being dependent on the power and frequency with which the transducer 8 is driven.

The sheet 69 includes approximately 1500 holes 77 of which only a proportion will emit droplets in use. Those of the holes 77 which do emit droplets tend to be concentrated in regions adjacent to the thickened elements 72, 73 and 74 and also in the central portion 76. The number of such holes 77 which do emit droplets will also depend on the amplitude of vibration induced in the membrane 13 and in a typical example the proportion of holes which emit droplets is about 10%.

The size of the droplets produced is closely dependent on the diameter of the holes 77 so that for different applications it may be necessary to use a sheet having different hole size.

Apparatus in accordance with the present invention may be used to dispense products in solution or suspension. Pharmaceutical products will generally require the presence of a preservative in aqueous solution such as benzalkonium chloride which has a tendency to reduce the surface tension of the resulting solution. When dispensing such solutions it is particularly important for the sheet 69 to be treated with a liquid repellant coating and for the external surface of the sheet to be as smooth as possible in order to reduce the tendency of the solution to wet the external surface of the sheet. Alternative liquid repellant coatings may be used such as silanes, fluorosilanes, micronised PTFE (polytetrafluoroethylene) particles and PTFE applied and heated in situ to form a conformal coating.

that the cross – section of each hole narrows in a direction from the rear surface towards a front surface of the membrane,

and vibrating the membrane such that droplets of the liquid are dispensed through the holes as an atomised spray.

10. A method as claimed in claim 9 wherein wetting of the front surface (78) of the membrane by the liquid is inhibited by means of a liquid repellant surface coating (80) applied to the front surface.

11. A method as claimed in any of claims 9 and 10 wherein the membrane is stiffened by means of a grid of support elements, the membrane comprising a sheet defining the array of holes and having thickened portions constituting the support elements.

12. A method as claimed in any of claims 9 to 11 wherein the liquid comprises a pharmaceutical product in aqueous solution or suspension.

FIG. 3.

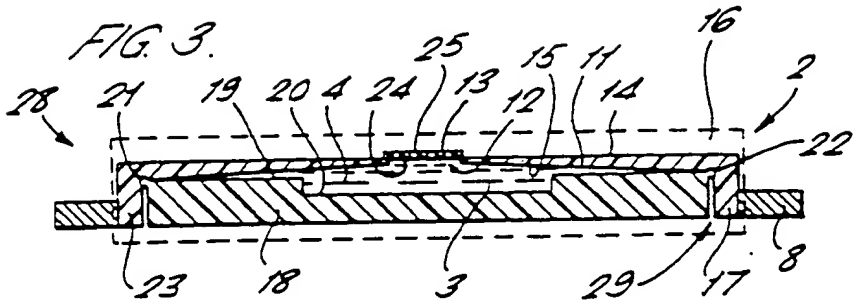

FIG. 4.

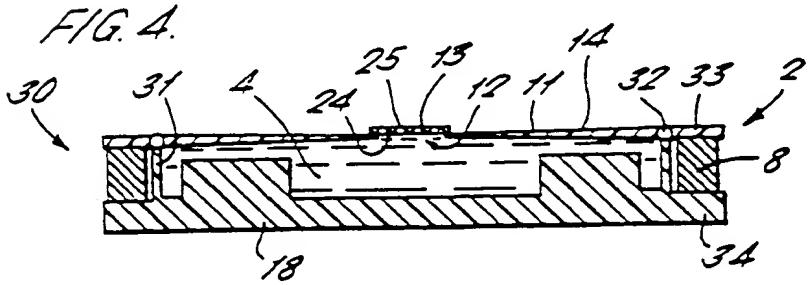

FIG. 5.

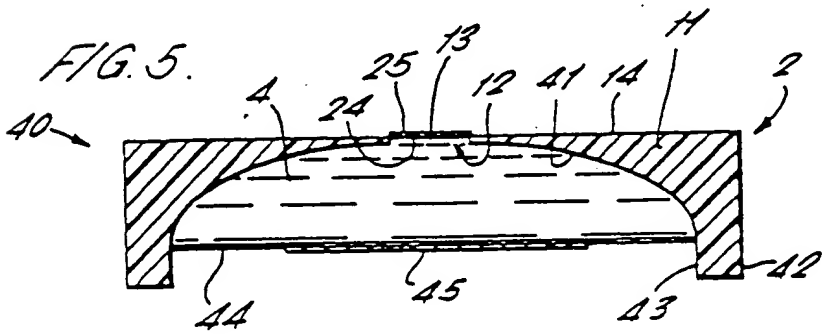

FIG 6.

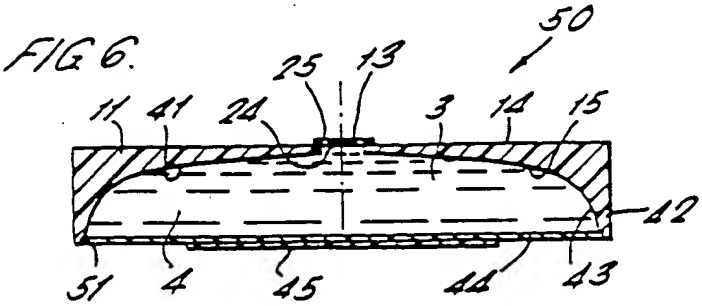

FIG. 10.